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A Survey on Retinal Microaneurysm Detection

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Abstract: Retinal Microaneurysms are the early clinically visible signs of Diabetic Retinopathy (DR). DR is the preventable blindness disease. For the prevention of disease Microaneurysms detection is important clinical process for the early diagnosis. This paper presents a review on latest methods for Microaneurysms detection. These techniques are evaluated and compared on the basis of their results such as Accuracy, sensitivity and specificity.
Keywords: Diabetic retinopathy, Microaneurysm.

1. Introduction

People with diabetes have an eye disease is called diabetic retinopathy which affects the retinal parts. In DR, retinal surface starts forming abnormal features such as Microaneurysms, haemorrhages, hard exudates, cotton wool spots or Soft exudates, neovascularization. These are as follows, and shown Fig.-1.

- **Microaneurysm (MA):** Microaneurysms is Small swelling, red isolated dot near the tiny blood vessels sometimes leaking fluid and blood into the retina. Microaneurysms are rounded small shape structures which is less than 125µm in diameter.
- **Haemorrhages:** Haemorrhages is a bleeding occurs in retinal surface.
- **Hard exudates:** Hard exudates are yellow-white intra retinal deposits which can vary from small specks
- **Soft exudates:** It is also known as a cotton-wool spots.
- **Neovascularisation:** Neovascularization is the formation of new blood vessels on retinal surface.

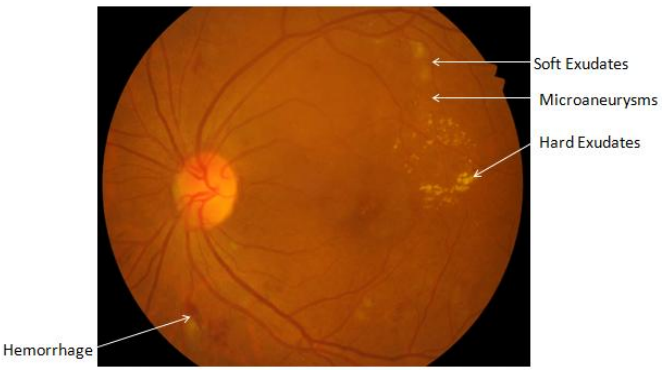
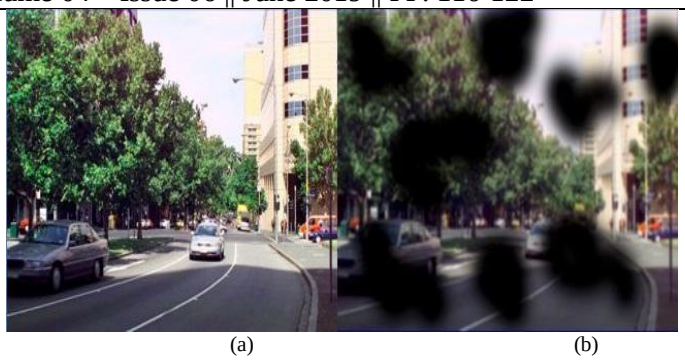


Fig.1-: Retinal fundus image contains DR features

These abnormal features may cause blurred vision, impairment of color vision, patches or streaks that block the person's vision, sudden and total loss of vision. Fig.-2(a) shows normal vision; (b) shows the vision has been affected by DR.



(a) (b)

Fig.-2: (a) Normal vision; (b) Vision affected by DR

DR is classified into two stages based on the features present in the retina. The classification of DR is as shown in Fig.-3. These stages are as follows;

- **Non-Proliferative Diabetic Retinopathy (NPDR):**
  NPDR is earliest stage of DR. In this stage retina contains abnormal features like Microaneurysms, Exudates, and Haemorrhages. Depending on presence of Microaneurysms NPDR is classified into mild, moderate and severe as follows:
  - Normal($MA = 0$)
  - Mild NPD$R(0 < MA < 5)$
  - Moderate NPDR($5 < MA < 15$)
  - Severe NPDR ($MA \geq 15$)

  Where, (MA) is the number of Microaneurysms [1].

- **Proliferative Diabetic Retinopathy (PDR):**
  PDR is the advanced stage of DR. In this stage retina starts growing new blood vessels which are known as neovascularization.

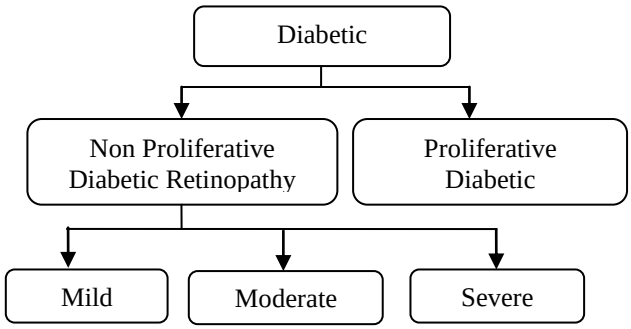


Fig.-3: Classification of DR

This paper is organized as follows; in section 2 literature review for microaneurysms detection method is presented. In section 3 general methodology is presented for microaneurysms detection. In section 4 fundus images database is presented. In section 5 performance measure and results for existing methods is described. Finally, in section 6 conclusions for paper is presented.

2. Literature Review

In last few years several methods proposed for automated microaneurysms detection. Hanung et al. [2] proposed method uses a matched filter for microaneurysms detection. Microaneurysms candidates are compared with their ground truths and annotations. Das et al. [3] proposed method uses entropy thresholding for microaneurysms detection. Naïve Bayes classifier used for classification. Wu et al. [4] proposed method uses

multi-scale and multi-orientation sum of matched filter (MMMF) for microaneurysms detection. KNN, SVM and LLDA classifier used for classification.

In the method proposed by Shah et al. [5], initial microaneurysms candidate regions are extraction done by using vessels removal technique and local thresholding. For the microaneurysms candidate statistical features extracted and rule-based classifiers used for classification. Dai et al. [6] proposed method for microaneurysms detection, initially candidate regions are extracted using a vessels removal technique and gradient vector technique. Several features for candidate regions are extracted such as geometry, contrast, intensity, edge, texture and region based. Class-imbalance classifier is used to classify candidate. Seoud et al. [7] approach for red lesions detection, for Microaneurysms candidate region extraction authors proposed a new set of shape features called Dynamic Shape Features. In recent years deep neural network based techniques are proposed by Shan et al. [8] and Haloi et al. [9] detection of Microaneurysms. CNN based approach is used by Budak et al. [10] for Microaneurysms detection.

Zhou et al. [11] proposed method use Multi-scale Gaussian Correlation Coefficients (MSCF) for candidate extraction. Intensity, shape and Gaussian filter based feature are extracted for candidates. Unsupervised classification method based on sparse PCA for classification. Wu et al. [12] proposed method for microaneurysms detection, initially candidate extraction is done by profile analysis technique and region growing technique. Different local and profile based features are extracted for microaneurysms candidate and KNN and AdaBoost classifiers used for classification. Wang et al. [13] presented method for microaneurysms detection, initially candidate regions are extracted using a dark object filtering technique. A set of statistical features for candidate regions extracted and kNN classifier used for classification. Sreng et al. [14] proposed method for microaneurysms detection, initially candidate extraction is done by using canny edges detection and maximum entropy thresholding. Finally, the morphological features extracted for candidate.

Manjaramkar et al. [15] proposed method for microaneurysms detection, initially candidate extraction is done by using coarse level and binary decision tree (DT) classifier and regression tree (CART) classifier used for classification. R Kamble et al. [16] proposed method use local rank transform for microaneurysms detection. Yuji et al. [17] presented three combines detector for microaneurysms candidate detection such as: the double-ring filter, shape index based on the Hessian matrix, and Gabor filter. DCNN used for classify microaneurysms from non-microaneurysms candidate. Dai et al. [18] presenting a clinical report for the identification of microaneurysms candidate regions which is based on the features image-to-text mapping and uses CNN for classification. Recently Behdad et al. [19] presented method for microaneurysms detection, initially microaneurysms candidate regions are extraction is done by gradient weighting technique and an iterative thresholding. Local convergence index filters based features and also with intensity and shape based features is extracted for each Microaneurysms candidate. Boosting classifier is used for classification of Microaneurysms candidate. Kumar et al. [20] proposed method for microaneurysms detection, initially candidate regions are extracted using principal component analysis (PCA), contrast limited adaptive histogram equalization (CLAHE), morphological process, averaging filtering, and Number and area based feature are extracted for candidates and SVM classifier used for classification.

Wen et al. [21] presented method for microaneurysms detection, initially microaneurysms candidate is extracted using small patches from fundus images and classify by Machine Learning Methods: random forest (RF), neural network, and support vector machine (SVM). Xu et al. [22] presented two combines detector for microaneurysms detection such as, MAs turnover and pathological risk factors. SVM classifier used for classification.

3. Methodology

Based on the review, general method is proposed for the detection of Microaneurysms is shown in Fig.4. Methods of Microaneurysms detection has divided into number of stages:

- **Pre-Processing:** Firstly, image pre-processing is performed on the green channel image because in green channel image has higher contrast with the background. The preprocessing is used for the reduction of noise in image and enhancing contrast of image because in noisy background feature extraction and abnormality detection algorithms gives poor results.

- **Candidate Extraction:** After the pre-processing, Microaneurysms candidate regions are detected. This stage is called Microaneurysms Candidate Extraction.

- **Feature extraction:** In this stage, suitable features extracted for the candidate regions. These features are several types different authors use different types of features for candidate. Features are important for classification stage.

- **Classification:** In this stage, different classifier used for the classification of features into Microaneurysms candidate (abnormal) and non-Microaneurysms candidate (normal). Classifier determines probability for each candidate.

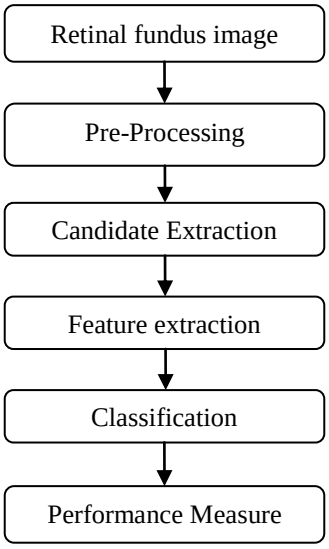


Fig.-4: Block diagram for Microaneurysms detection method

4. Image Dataset

The Microaneurysms detection method is applied on publically available datasets which are as follows,

- **IDRiD:** IDRiD (Indian Diabetic Retinopathy Image Dataset) is the first database representing on an Indian population [23]. It consists of 516 images. It provides DR severity level and diabetic macular edema for each image.

- **E-ophtha-MA:** The E-ophtha-MA dataset [24] consists of 233 healthy images and 148 images with Microaneurysms.

- **DiaretDB1:** The DiaretDB1 dataset [25] is consists of 89 fundus images. 84 images of these images contain signs of DR and 5 images of these images are normal.

- **ROC:** The Retinopathy online challenge (ROC) dataset [26] is Consists of 50 train images and 50 test images. For 50 train images 'gold standard' is provided and for 50 test images 'gold standard' is not provided.

- **MESSIDOR:** The MESSIDOR dataset [27] is contains of 1200 images. 800 images with pupil dilation and 400 without dilation.

- **RC-RGB-MA:** The RC-RGB-MA dataset (RGB fundus camera) [28] consists of 250 images.

- **RC-SLO-MA:** The RC-SLO-MA dataset (scanning laser ophthalmoscope) [29] is consists of 58 fundus images.

These seven publicly available dataset specifications are given in Table-1.

Table-1
Dataset specification

Dataset	Modality	Image size	FOV
IDRiD[23]	RGB	4288×2848	50◦
e-ophtha-MA[24]	RGB	1440×960–2544×1696	45◦
DiaretDB1[25]	RGB	1500×1152	50◦
ROC[26]	RGB	768×567–1394 × 1392	45◦
MESSIDOR[27]	RGB	1440×960–2304 × 1536	45◦
RC-RGB-MA[28]	RGB	2595×1944	45◦
RC-SLO-MA[29]	SLO	1024×1024	45◦

5. Result

The performance of the Microaneurysms detection systems is based on Accuracy, Sensitivity and Specificity which are given as follows,

- Accuracy - The correct value of a measurements or calculations for people with disease condition.

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+TN+FN} \qquad (1)$$

- Sensitivity - The ability to correct detection of people with disease condition.

$$\text{Sensitivity} = \frac{TP}{TP+FN} \qquad (2)$$

- Specificity - The ability to correct detection of people without disease condition.

$$\text{Specificity} = \frac{TN}{TN+FP} \qquad (3)$$

Where, TP i.e. True Positive - Correct identification of Microaneurysms candidate founded as Microaneurysms candidate.
TN i.e. True Negative - Correct rejection of non-Microaneurysms candidate founded as non-Microaneurysms candidate.
FP i.e. False Positive - Incorrect identification of non-Microaneurysms candidate founded as Microaneurysms candidate.
FN i.e. False Negative - Incorrect rejection of Microaneurysms candidate found as non-Microaneurysms candidate.
Evaluated results for existing method for microaneurysms detection are given in Table-2.

Table-2
Results for different existing methods for microaneurysms detection

Authors	Dataset	Candidates Extraction Method	Classifier	Accuracy	Sensitivity	Specificity
Hanung et al. [2]	__	Matched filter	__	99.9752%	91.0603%	99.9752%
Das et al. [3]	ROC, DiaretDB1	Entropy Thresholding	Naïve Bayes classifier		0.421 and 0.477 resp.	
Shah et al. [5]	ROC	Vessels removal technique and local thresholding	Rule-based classifiers	__	48.21%	__
Dai et al. [6]	ROC, DiaretDB1	Vessels removal technique and gradient vector technique	Class-imbalance classifier	__	43.3%	__
Shan et al. [8]	DiaretDB1	__	Deep neural network	91.38%	__	91.60%
Haloi et al. [9]	ROC, Messidor and Diaretdb1v2	__	Deep neural network	95%	97%	94%

Wang et al. [13]	ROC, DiaretDB1	Dark object filtering technique	KNN classifiers	__	51.7%	__
Manjaramkar et al. [15]	DiaretDB1	Coarse level	Decision tree (DT) classifier	98.6%	92.9%	99.9%
R Kamble et al. [16]	E-Ophtha, Diaretdb1, and Messidor	Local rank transform	__	94.34 %, 96.04%,96.31 % resp.	__	__
Yuji et al. [17]	DiaretDB1	The double-ring filter, shape based on the Hessian matrix, and Gabor filter	DCNN classifier	__	84%	__
Dai et al. [18]	DiaretDB1	Image-to-text mapping Model	CNN Classifier	96.1%	87.7%	__
Kumar et al. [20]	DiaretDB1	PCA	SVM Classifier	_	96%	92%
Xu et al. [22]	Grampian	Microaneurysms turnover and pathological risk factors	SVM Classifier	__	89%	88%

6. Conclusion

In this paper we take a review on researchers works that has been done in last few years for automated microaneurysms detection. It is found that firstly preprocessing is performed on green channel image. After the preprocessing, candidate region extraction is done and many effective features for these candidate regions are extracted in the fundus images which can be used for classification. Classifier performance is measured for these methods. In future fast, accurate and efficient method for microaneurysms detection at low cost for early stage diagnoses of DR.

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